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(54) **SERVICE RESOURCE ALLOCATION**

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G06F 9/50 (2006.01)
G06F 9/54 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 9/5083*** (2013.01); ***G06F 9/50*** (2013.01); *G06F 9/547* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0078532	A1 *	4/2004	Tremaine	711/160
2012/0159367	A1 *	6/2012	Calcaterra et al.	715/771
2014/0058871	A1 *	2/2014	Marr et al.	705/26.1
2014/0137110	A1 *	5/2014	Engle et al.	718/1

* cited by examiner

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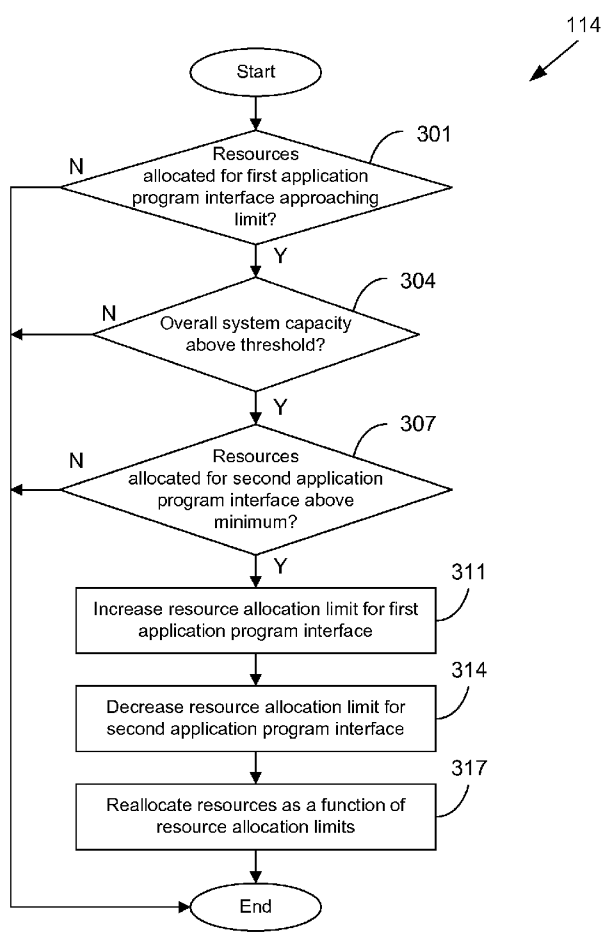
(57) **ABSTRACT**

Disclosed are various embodiments for a resource allocation application. Usage data for application program interfaces is aggregated over time. Limits for an allocation of resources for each of the application program interfaces are calculated as a function of the usage data. Limits are recalculated as new application program interfaces are added.

22 Claims, 5 Drawing Sheets



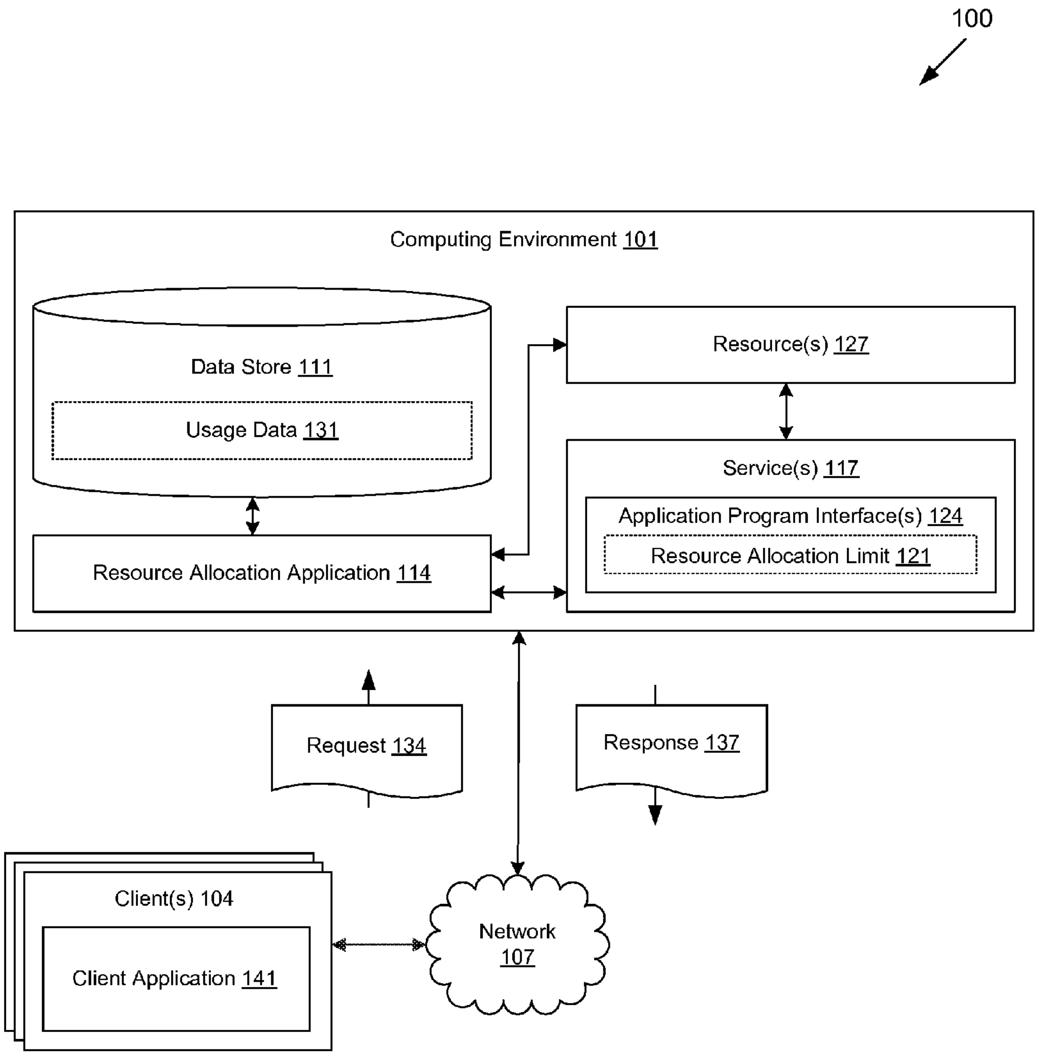

100
Computing Environment 101
Data Store 111
Usage Data 131
Resource(s) 127
Service(s) 117
Application Program Interface(s) 124
Resource Allocation Limit 121
Resource Allocation Application 114
Request 134
Response 137
Client(s) 104
Client Application 141
Network
107

FIG. 1

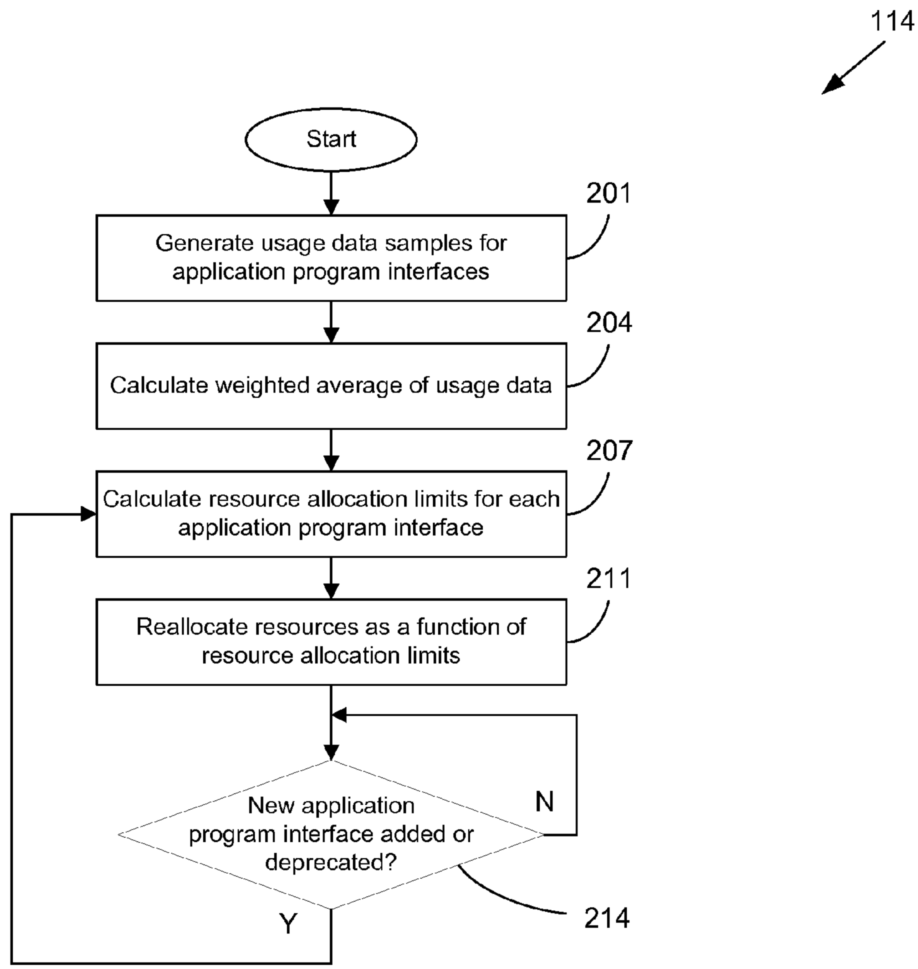

114
Start
201
Generate usage data samples for application program interfaces
204
Calculate weighted average of usage data
207
Calculate resource allocation limits for each application program interface
211
Reallocate resources as a function of resource allocation limits
New application program interface added or deprecated?
N
Y
214

FIG. 2

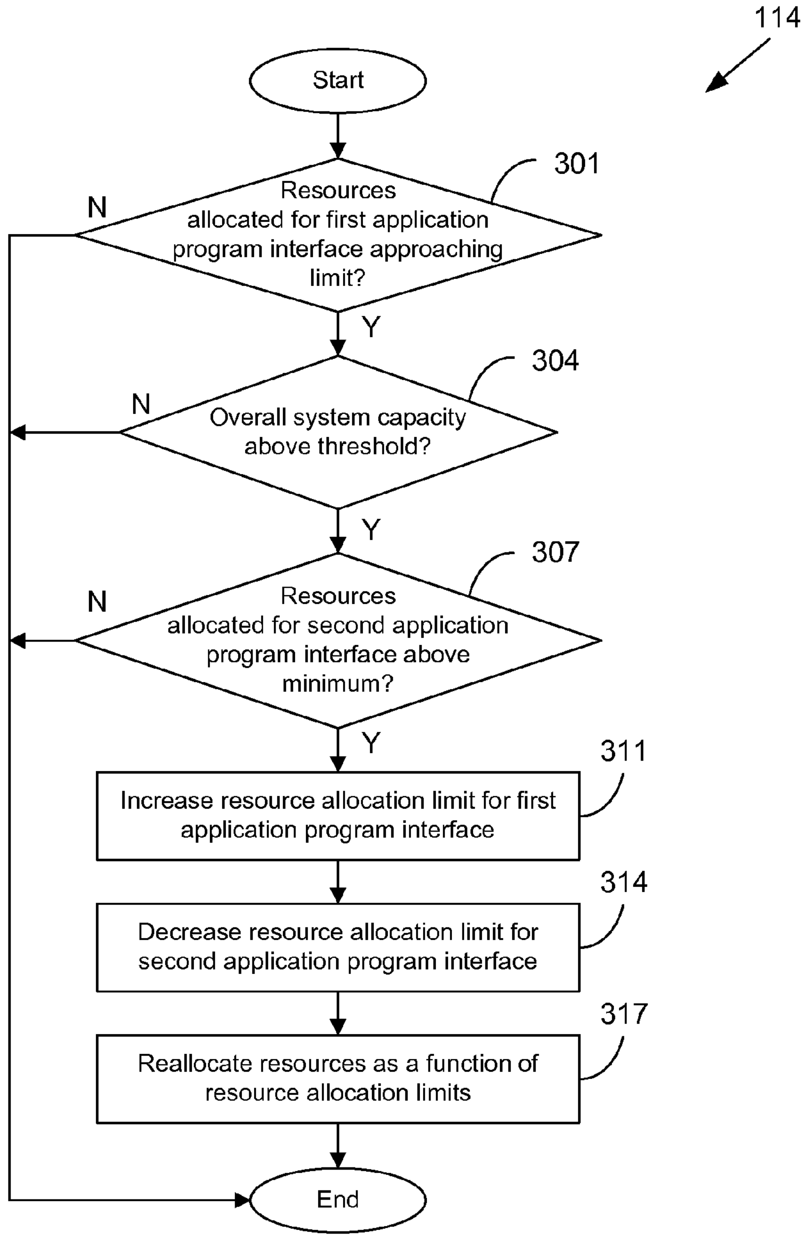

114
Start
Resources allocated for first application program interface approaching limit?
301
N
Y
Overall system capacity above threshold?
304
N
Y
Resources allocated for second application program interface above minimum?
307
N
Y
Increase resource allocation limit for first application program interface
311
Decrease resource allocation limit for second application program interface
314
Reallocate resources as a function of resource allocation limits
317
End

FIG. 3

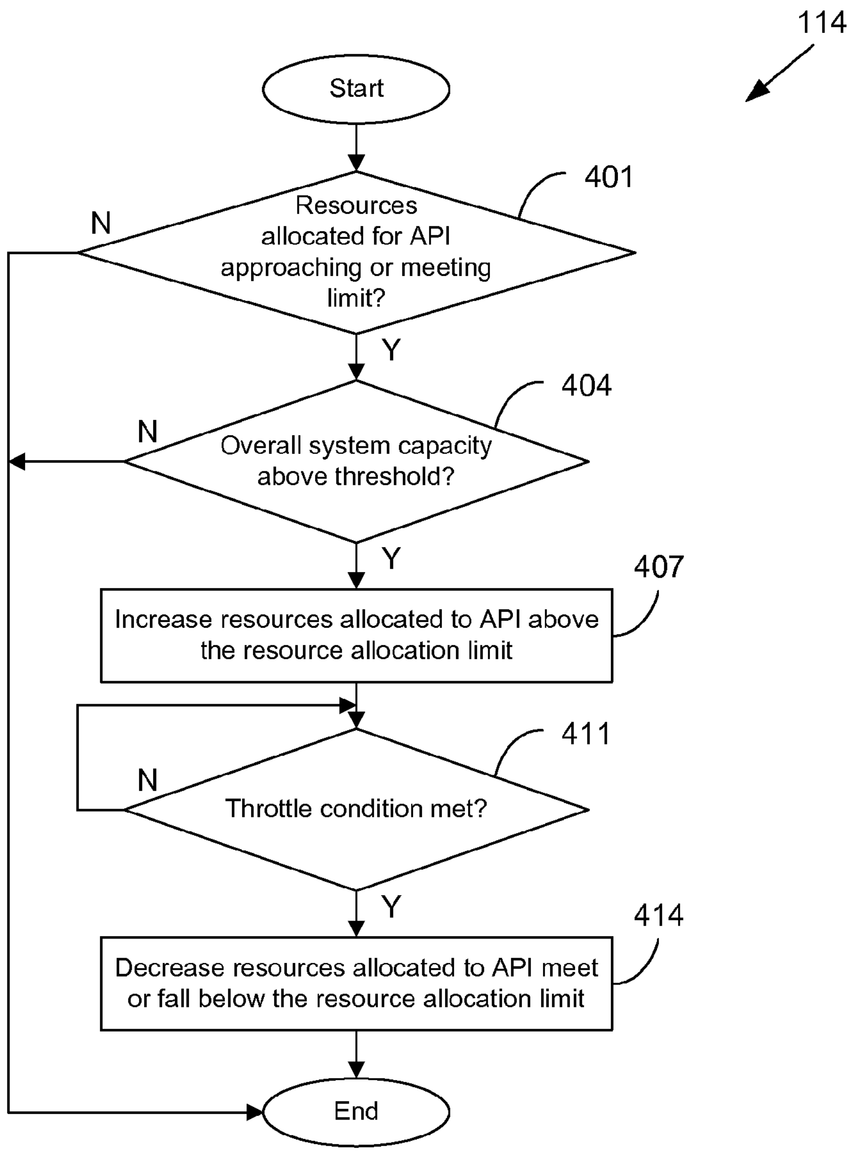

114
Start
401
Resources allocated for API approaching or meeting limit?
N
Y
404
Overall system capacity above threshold?
N
Y
407
Increase resources allocated to API above the resource allocation limit
411
Throttle condition met?
N
Y
414
Decrease resources allocated to API meet or fall below the resource allocation limit
End

FIG. 4

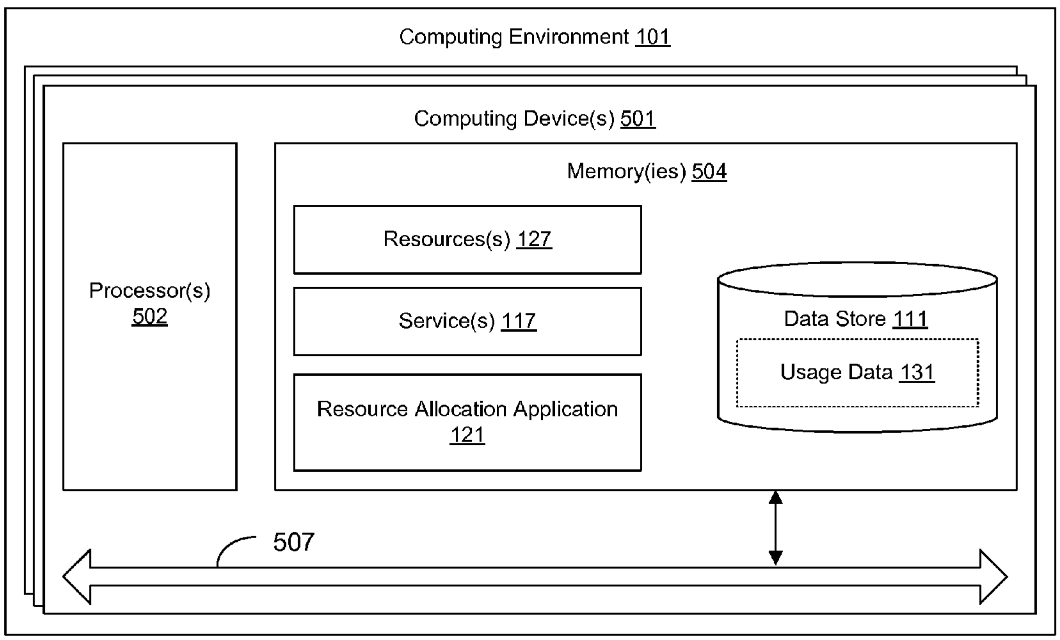

Computing Environment 101
Computing Device(s) 501
Memory(ies) 504
Resources(s) 127
Service(s) 117
Resource Allocation Application 121
Data Store 111
Usage Data 131
Processor(s) 502
507

FIG. 5

SERVICE RESOURCE ALLOCATION

BACKGROUND

Services may share a pool of available resources to perform their functions. Problems arise when resource distributions result in service unavailability.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a drawing of a networked environment according to various embodiments of the present disclosure.

FIG. **2** is a flowchart illustrating one example of functionality implemented as portions of a resource allocation application executed in a computing environment in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

FIG. **3** is a flowchart illustrating one example of functionality implemented as portions of resource allocation application executed in a computing environment in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

FIG. **4** is a flowchart illustrating one example of functionality implemented as portions of resource allocation application executed in a computing environment in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

FIG. **5** is a schematic block diagram that provides one example illustration of a computing environment employed in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

Computing resources are often shared amongst many executed services. Examples of resources may include threads, disk space, network bandwidth, or other resources. When a service or an application program interface (API) of a service uses an excessive amount of resources, it may leave the other services or APIs lacking in resources. This results in unavailability for clients attempting to access the services or APIs.

Limits can be imposed with respect to the APIs in order to prevent one API from monopolizing the resource pool. Manually implemented limits have several disadvantages. As static values, the manually implemented limits cannot adjust to changes in a dynamic computing environment. Limits cannot be increased in periods of available system capacity, and cannot be decreased to account for API unavailability. Additionally, as new APIs that access the same resource pool are added, new limits must be imposed across all APIs which increases the administrator workload.

A resource allocation application dynamically determines resource allocation limits with respect to the APIs. The limits are recalculated as new APIs are added. The limits may be calculated as a function of past usage data with respect to the individual APIs, priority tiers assigned to the APIs, or other data. Additionally, resource limits can be reallocated between subsets of APIs in periods of high system capacity or heavy transaction loads on the APIs.

In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same.

With reference to FIG. **1**, shown is a networked environment **100** according to various embodiments. The networked environment **100** includes a computing environment **101** and a client **104**, which are in data communication with each other via a network **107**. The network **107** includes, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, or other suitable networks, etc., or any combination of two or more such networks.

The computing environment **101** may comprise, for example, a server computer or any other system providing computing capability. Alternatively, the computing environment **101** may employ a plurality of computing devices that may be employed that are arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices may be located in a single installation or may be distributed among many different geographical locations. For example, the computing environment **101** may include a plurality of computing devices that together may comprise a cloud computing resource, a grid computing resource, and/or any other distributed computing arrangement. In some cases, the computing environment **101** may correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time.

Various applications and/or other functionality may be executed in the computing environment **101** according to various embodiments. Also, various data is stored in a data store **1111** that is accessible to the computing environment **101**. The data store **111** may be representative of a plurality of data stores **111** as can be appreciated. The data stored in the data store **111**, for example, is associated with the operation of the various applications and/or functional entities described below.

The components executed on the computing environment **101**, for example, include a resource allocation application **114** and services **117**, and other applications, services, processes, systems, engines, or functionality not discussed in detail herein. The resource allocation application **114** is executed to calculate resource allocation limits **121** for APIs **124** of the services **117**, thereby limiting an amount of resources **127** available to execute the functionality implemented in the APIs **124**. The resource allocation application **114** may also facilitate the allocation of the resources **127** to the APIs **124** as a function of the resource allocation limits **121**.

The resource allocation limits **121** may be calculated as a function of usage data **131** of the APIs **124**. Usage data **131** may comprise, for example, an amount of transactions per second executed with respect to a corresponding one of the APIs over a period of time. Usage data **131** may also comprise an amount of processing power, network bandwidth, disk reads, disk writes, socket connections, database connections, or other data used over a period of time. The usage data **131** may comprise aggregates of the data over a time period, samples taken at predefined intervals, or other information. The usage data **131** may be generated by a data sampling or aggregation agent, generated as a function of log or record data, or generated by some other approach.

In embodiments in which the resource allocation limits **121** are calculated as a function of usage data **131**, the resource allocation application **114** may calculate an aggregate value with respect to the usage data **131**. For example, in calculating a resource allocation limit **121** for an API **124**, the resource allocation application **114** may calculate an average transactions per second as a function of sampled transactions per second embodied in the usage data **131**.

Additionally, the resource allocation application **114** may calculate a weighted average of the usage data **131**. Weights assigned to the usage data **131** may be a function of the age of the usage data **131**. For example, older usage data **131** may be weighted higher than newer usage data **131**. Conversely, newer usage data **131** may be weighted higher than older usage data **131**. Weighted averages of the usage data **131** may be calculated by other approaches as well. Other aggregate functions such as minimums, maximums, summations, or other aggregate functions may also be used to calculate the resource allocation limit **121** as a function of the usage data **131**.

The resource allocation application **114** may calculate the resource allocation limits **121** as a function of priority tiers assigned to the APIs **124**. As a non-limiting example, each of the APIs **124** may be assigned one of a high, medium, and low priority tier. In such an embodiment the corresponding one of the resource allocation limits **121** may be calculated as being higher for high tier APIs **124** and lower for low tier APIs **124**. The resource allocation application **114** may also calculate the resource allocation limits **121** by another approach.

The resource allocation application **114** may recalculate the resource allocation limits **121** in response to an event, a predefined condition, or other criteria. For example, the resource allocation application **114** may recalculate the resource allocation limits **121** in response to a new API **124** being added to a set of APIs **124** associated with the same service **117** or sharing the same pool of resources **127**. The resource allocation application **114** may recalculate the resource allocation limits **121** in response to input from a user or administrator of the computing environment **101**, a state of resource **127** usage, or in response to another event or condition.

In some embodiments, the resource allocation application **114** may perform a reallocation of resource allocation limits **121** for a subset of the APIs **124**. For example, a first API **124** may "steal" a portion of the resource allocation limit **121** corresponding to a second API **124**. This comprises increasing the resource allocation limit **121** corresponding to the first API **124** and decreasing the resource allocation limit **121** corresponding to the second API **124**.

The reallocation of the resource allocation limits **121** may be performed responsive to an event, predefined condition, or other criteria. In one embodiment, resource allocation limits **121** are reallocated responsive to a resource **127** usage of a first API **124** approaching the resource allocation limit **121** corresponding to the first API **124**. This may comprise the resource **127** usage exceeding a threshold determined as a function of the resource allocation limit **121**, the resource **127** usage equaling the resource allocation limit **121**, or some other approach. Responsive to the resource **127** usage of the first API **124** approaching the resource allocation limit **121**, the resource allocation application **114** will decrease the resource allocation limit **121** of a second API **124** and increase the resource allocation limit **121** of the first API **124**.

The second API **124** from which the resource allocation limits **121** are reallocated may be determined by the resource allocation application **114** as a function of resource **127** usage with respect to the second API **124**. For example, the second API **124** may comprise an API **124** whose resource **127** usage is below a threshold with respect to the corresponding resource allocation limit **121**. In other embodiments, the second API **124** may be determined as a function of the corresponding resource allocation limit **121** being above a minimum threshold. For example, the second API **124** may be the one of the APIs **124** whose resource allocation limit **121** after reallocation meets or exceeds a minimum value. Other criteria may also be used to determine the second API **124** from which the resource allocation limits **121** are reallocated.

Reallocating the resource allocation limits **121** may be subject to conditions or other criteria. In some embodiments, the resource allocation limits **121** may only be reallocated if an available system or resource **127** capacity exceeds a threshold. For example, even if the resource **127** usage of a first API **124** approaches the resource allocation limit **121**, the resource allocation limits **121** may only be reallocated if at least twenty-five percent of the system capacity is available.

Additionally, in embodiments in which resource allocation limits **121** are reallocated from APIs **124** having resource allocation limits **121** above a minimum threshold, the resource allocation limits **121** may be reallocated subject to there being an API **124** having a resource allocation limit **121** above the minimum threshold. Other conditions may also exist for reallocating the resource allocation limits **121**.

In embodiments in which the resource allocation application **114** facilitates the allocation of the resources **127** as a function of the resource allocation limits **121**, the resource allocation application **114** may allocate an amount of resources **127** to an API **124** above the corresponding resource allocation limit **121** responsive to a condition or event. For example, an amount of resources **127** allocated to an API **124** may meet the corresponding resource allocation limit **121**, an increased load is being placed on the API **124**, and an amount of available system capacity exceeds a minimum threshold. In such an example, the resource allocation application **114** may allocate resources **127** to the API **124** above the corresponding resource allocation limit **121**.

The resource allocation application **114** may also throttle back resources **127** allocated to an API **124** above the corresponding resource allocation limit **121** subject to some condition or event. Such conditions may include, for example, the amount of allocated resources **127** exceeding the resource allocation limit **121** for a predefined amount of time, the amount of overall system capacity falling below a minimum threshold, or some other event.

Services **117** comprise functionality implemented in the computing environment **101** to facilitate the execution of applications or other services **117** executed in the computing environment **101**. The services **117** may be executed to, for example, facilitate the processing of requests **134** obtained from and communicating responses **137** to clients **104**. Each service **117** may implement one or more APIs **124** to facilitate their operation. The APIs **124** may be exposed to clients **104** or other functionality implemented in the computing environment **101**. Each API **124** corresponds to a resource allocation limit **121** establishing a maximum threshold for resource **127** in executing calls to the API **124**. Resources **127** may comprise any capability that must be scheduled, assigned, or controlled to assure nonconflicting usage by the APIs **124**. As non-limiting examples, resources **127** may comprise threads, processing power, network bandwidth, disc access, input/output traffic, database connections, used or allocated memory, socket connections, open sockets, or other computational resource used to facilitate the execution of API **124** calls.

The data stored in the data store **111** includes, for example, usage data **131**, and potentially other data.

The client **104** is representative of a plurality of client devices that may be coupled to the network **107**. The client **104** may comprise, for example, a processor-based system such as a computer system. Such a computer system may be embodied in the form of a desktop computer, a laptop computer, personal digital assistants, cellular telephones, smartphones, set-top boxes, music players, web pads, tablet computer systems, game consoles, electronic book readers, or other devices with like capability.

The client **104** may be configured to execute various applications such as a client application **141** and/or other applications. The client application **141** may be executed in a client **104**, for example, to access network content served up by the computing environment **101** and/or other servers. To this end, the client application **141** may comprise, for example, a browser, a dedicated application, etc. The client **104** may be configured to execute applications beyond the client application **141** such as, for example, email applications, social networking applications, word processors, spreadsheets, and/or other applications.

Next, a general description of the operation of the various components of the networked environment **100** is provided. To begin, clients **104** communicate requests **134** to the computing environment **101**. Services **117** are executed to satisfy these requests **134**. Satisfying the requests **134** may be facilitated by APIs **124** associated with a respective one of the services **117**.

Each of the APIs **124** comprises a resource allocation limit **121** establishing a maximum amount of resources **127** that may be allocated for executing API **124** calls. The resources **127** may comprise threads, network bandwidth, disk access, or other computational functionality available in the computing environment **101**.

As API **124** calls are executed to satisfy the requests **134**, usage data **131** is aggregated by the resource allocation application **114**. Usage data **131** may comprise an amount of transactions per second executed with respect to a corresponding one of the APIs **124**, resource **127** consumption or usage, and potentially other data. The usage data **131** may be associated with a time period during which the usage data **131** was aggregated or sampled. Satisfaction of the requests **134** may further comprise communicating responses **137** to the client. API **124** calls and associated usage data **131** may be generated responsive to other events, such as internal functionality executed in the computing environment **101**, or by another approach.

The resource allocation application **114** then calculates the resource allocation limits **121** of the APIs **124**. The resource allocation limits **121** may be calculated or recalculated responsive to some event, condition, or other critera. For example, the event may comprise an addition or deprecation of an API **124** to a collection of APIs **124** associated with the same service **117** or shared pool of resources **127**. The event may also comprise input for a user or administrator of the computing environment **101**. A condition may comprise the computing environment **101** or resource **127** usage embodying a predefined state. The resource allocation application **114** may also recalculate the resource allocation limits **121** responsive to other criteria.

Calculating the resource allocation limit **121** for an API **124** may comprise applying an aggregate function to that of the usage data **131** associated with the API **124**. For example, the resource allocation application **114** may apply a weighted average to the resource **127** usage embodied in the usage data **131** with respect to the API **124**. The weight applied to the usage data **131** may increase with respect to the age of the usage data **131** such that older usage data **131** receives a higher weight. Other functions may also be applied to the usage data **131** to generate the resource allocation limits **121**.

The resource allocation limits **121** may also be calculated as a function of priority tiers associated with the APIs **124**, or as a function of other data.

The resource allocation application **114** may reallocate resource allocation limits **121** with respect to a pair of APIs **124**, thereby allowing one API **124** to "steal" resource allocation limits **121** from another API **124**. Reallocating the resource allocation limits **121** may be initiated responsive to a resource **127** usage of one API **124** approaching the corresponding resource allocation limit **121**. This may comprise the resource **127** usage equaling the resource allocation limit **121**, exceeding a threshold generated with respect to the resource allocation limit **121**, or meeting some other criteria. Reallocating the resource allocation limits **121** of a pair of APIs **124** may comprise increasing the resource allocation limit **121** of a first API **124** and decreasing the resource allocation limit **121** of a second API **124**, or another approach.

In some embodiments, resource allocation limits **121** are associated with minimum threshold values. In such embodiments, the resource allocation limit **121** to be decreased may not be decreased to a value below the minimum threshold value. The minimum threshold value may be defined with respect to the corresponding API **124**, applied to all APIs **124**, or a subset of APIs **124**.

Reallocating the resource allocation limits **121** may be performed subject to a predefined condition. For example, the resource allocation application **114** may perform a resource allocation limit **121** reallocation subject to an overall system capacity of the computing environment **101** or an available resource **127** capacity exceeding a minimum threshold. Additionally, the reallocation may be performed subject to there being at least one API whose resource allocation limit **121** exceeds a minimum threshold value.

In some embodiments, the resource allocation application **114** may calculate, recalculate, reallocate, or modify the resource allocation limits **121** subject to a maximum change threshold. The maximum change threshold embodies an amount by which a resource allocation limit **121** may be modified. The maximum change threshold may be defined with respect to a period of time. For example, a maximum change threshold may dictate that a resource allocation limit **121** may not be changed by more than ten percent of an initial value per day. The maximum change threshold may also be enforced by another approach.

After the resource allocation limits **121** have been calculated, recalculated, reallocated, or otherwise modified, the resource allocation application **114** may then modify the resources **127** allocated to the APIs **124** to reflect modified resource allocation limits **121**. For example, if an amount of allocated thread resources **127** is greater than a subsequently calculated resource allocation limit **121**, the resource allocation application **114** may initiate a termination of a subset of the threads allocated to the respective API **124**. As another example, an API **124** whose resource allocation limit **121** is increased may have additional threads created to facilitate completion of the respective API **124** calls. Other actions may also be taken in response to the resource allocation application **114** modifying the resource allocation limits **121**.

In some embodiments, the resource allocation application **114** may increase an amount of resources **127** allocated to an API **124** above the corresponding resource allocation limit **121** subject to a condition or event. For example, such conditions may include an increased load being placed on an API **124** whose allocated resources **127** meet the corresponding resource allocation limit, and an overall available system capacity exceeding a threshold. Other events or conditions may also trigger an allocation of resources **127** above a resource allocation limit **121**.

If an amount of resources **127** allocated to an API **124** is above the corresponding resource allocation limit **121**, the resource allocation application **114** may throttle back the amount of allocated resources **127** to meet or fall below the corresponding resource allocation limit **121** responsive to some event or condition. For example, such a condition may comprise an amount of resources **127** being allocated above the corresponding resource allocation limit **121** for a predefined amount of time. Such a condition may also comprise an amount of available system capacity falling below a threshold. Other conditions or events may also trigger a throttling back of an amount of allocated resources **127** to meet or fall below a corresponding resource allocation limit **121**.

Referring next to FIG. **2**, shown is a flowchart that provides one example of the operation of a portion of the resource allocation application **114** (FIG. **1**) according to various embodiments. It is understood that the flowchart of FIG. **2** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the resource allocation application **114** as described herein. As an alternative, the flowchart of FIG. **2** may be viewed as depicting an example of steps of a method implemented in the computing environment **101** (FIG. **1**) according to one or more embodiments.

Beginning with box **201**, the resource allocation application **114** generates usage data **131** (FIG. **1**) samples for a set of APIs **124** (FIG. **1**). Generating the usage data **131** samples may comprise querying a data store **111** (FIG. **1**) storing a collection of usage data **131**. This may also comprise querying log data or other data maintained with respect to the APIs **124**. Generating the usage data **131** samples may also be performed by another approach.

Next, in box **204**, the resource allocation application **114** calculates a weighted average of the usage data **131** samples. This may comprise applying a weight to the usage data **131** that increases with the age of the usage data **131**, or by another approach. In box **207**, the resource allocation application **114** calculates the resource allocation limits **121** (FIG. **1**) for each of the APIs **124**. This may be performed as a function of the weighted average of the usage data **131** corresponding to a respective one of the APIs **124**. This may also be performed as a function of a priority tier associated with the APIs **124**, or by another approach.

In box **211**, the resources **127** (FIG. **1**) are reallocated as a function of the resource allocation limits **121**. This may comprise decreasing an amount of resources **127** allocated to an API **124** whose resource allocation limit **121** was decreased, or another action.

In box **214**, the resource allocation application **114** waits until a new API **124** has been added to the collection of APIs **124**. When the API is added, the process moves to box **207**, where the resource allocation limits **121** are recalculated and the amounts of allocated resources **127** adjusted in box **211**.

Referring next to FIG. **3**, shown is a flowchart that provides one example of the operation of at least a portion of the resource allocation limit **121** (FIG. **1**) reallocation functionality of the resource allocation application **114** (FIG. **1**) according to various embodiments. It is understood that the flowchart of FIG. **3** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the resource allocation application **114** as described herein. As an alternative, the flowchart of FIG. **3** may be viewed as depicting an example of steps of a method implemented in the computing environment **101** (FIG. **1**) according to one or more embodiments.

In box **301**, the resource allocation application **114** determines if the resources **127** (FIG. **1**) allocated for a first API **124** (FIG. **1**) is approaching the resource allocation limit **121**. This may comprise determining if the allocated resources **127** equals the resource allocation limit **121**, exceeds some threshold calculated with respect to the resource allocation limit **121**, or exceeds some other threshold.

If the resources **127** allocated to the first API **124** do not approach the resource allocation limit **121** the process ends. Otherwise, the process proceeds to box **304**, where the resource allocation application **114** determines if the overall system capacity is above a threshold. If the system capacity is below the threshold, the process ends. Otherwise, the process proceeds to box **307**.

In box **307** the resource allocation application **114** determines if the resources **127** allocated to a second API **124** are above a minimum amount. The minimum may be defined with respect to the API **124**, a corresponding service **117** (FIG. **1**), or with respect to an entirety or a subset of the APIs **124**. The minimum may also be defined as a function of other data. If the resources **127** allocated to the second API are at or below the minimum, the process ends. Otherwise, the process proceeds to box **311**.

In box **311**, the resource allocation limit **121** corresponding to the first API **124** is increased. In box **314**, the resource allocation limit **121** corresponding to the second API **124** is increased. In box **317**, resources **127** allocated to the first and second API **124** are reallocated to reflect the new resource allocation limits **121**, after which the process ends.

Referring next to FIG. **4**, shown is a flowchart that provides one example of the operation of at least a portion of the resource **127** (FIG. **1**) allocation functionality of the resource allocation application **114** (FIG. **1**) according to various embodiments. It is understood that the flowchart of FIG. **4** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the resource allocation application **114** as described herein. As an alternative, the flowchart of FIG. **4** may be viewed as depicting an example of steps of a method implemented in the computing environment **101** (FIG. **1**) according to one or more embodiments.

In box **401**, the resource allocation application **114** determines if the amount of resources **127** allocated for an API **124** (FIG. **1**) is approaching or meets the corresponding resource allocation limit **121** (FIG. **1**). This may comprise determining if the allocated resources **127** equals the resource allocation limit **121**, exceeds some threshold calculated with respect to the resource allocation limit **121**, or exceeds some other threshold.

If the resources **127** allocated to the API **124** do not approach or meet the corresponding resource allocation limit **121**, the process ends. Otherwise, the process proceeds to box **404**, where the resource allocation application **114** determines if the overall system capacity is above a threshold. If the system capacity is below the threshold, the process ends. Otherwise, the process proceeds to box **407**.

In box **407** the resource allocation application **114** increases an amount of resources **127** allocated to the API **124** to a value above the corresponding resource allocation limit **121**. In box **411**, the resource allocation application **114** determines if a throttling condition is met. The throttling condition may comprise an amount of resources **127** being allocated to the API **124** above the corresponding resource allocation limit **121** for a predefined amount of time, a transaction load being placed on the API **124** falling below a threshold, an amount of available system capacity falling below a threshold, or another event. In box **414**, when a throttle condition is met, the resource allocation application **114** decreases the amount of resources **127** allocated to the API **124** to an amount at or below the corresponding resource allocation limit **121**, after which the process ends.

With reference to FIG. **5**, shown is a schematic block diagram of the computing environment **101** (FIG. **1**) according to an embodiment of the present disclosure. The computing environment **101** includes one or more computing devices **501**. Each computing device **501** includes at least one processor circuit, for example, having a processor **502** and a memory **504**, both of which are coupled to a local interface **507**. To this end, each computing device **501** may comprise, for example, at least one server computer or like device. The local interface **507** may comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

Stored in the memory **504** are both data and several components that are executable by the processor **502**. In particular, stored in the memory **504** and executable by the processor **502** are a resource allocation application **114** (FIG. **1**), services **117** (FIG. **1**) facilitated by resources **127** (FIG. **1**), and potentially other applications. Also stored in the memory **504** may be a data store **111** (FIG. **1**) and other data. In addition, an operating system may be stored in the memory **504** and executable by the processor **502**.

It is understood that there may be other applications that are stored in the memory **504** and are executable by the processor **502** as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed such as, for example, C, C++, C#, Objective C, Java®, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Flash®, or other programming languages.

A number of software components are stored in the memory **504** and are executable by the processor **502**. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor **502**. Examples of executable programs may be, for example, a compiled program that can be translated into machine code in a format that can be loaded into a random access portion of the memory **504** and run by the processor **502**, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory **504** and executed by the processor **502**, or source code that may be interpreted by another executable program to generate instructions in a random access portion of the memory **504** to be executed by the processor **502**, etc. An executable program may be stored in any portion or component of the memory **504** including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, USB flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other memory components.

The memory **504** is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory **504** may comprise, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, and/or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may comprise, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may comprise, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

Also, the processor **502** may represent multiple processors **502** and/or multiple processor cores and the memory **504** may represent multiple memories **504** that operate in parallel processing circuits, respectively. In such a case, the local interface **507** may be an appropriate network that facilitates communication between any two of the multiple processors **502**, between any processor **502** and any of the memories **504**, or between any two of the memories **504**, etc. The local interface **507** may comprise additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor **502** may be of electrical or of some other available construction.

Although the resource allocation application **114**, and other various systems described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, etc. Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

The flowcharts of FIGS. **2**, **3**, and **4** show the functionality and operation of an implementation of portions of the resource allocation application **114**. If embodied in software, each block may represent a module, segment, or portion of code that comprises program instructions to implement the specified logical function(s). The program instructions may be embodied in the form of source code that comprises human-readable statements written in a programming language or machine code that comprises numerical instructions recognizable by a suitable execution system such as a processor **502** in a computer system or other system. The machine code may be converted from the source code, etc. If embodied in hardware, each block may represent a circuit or a number of interconnected circuits to implement the specified logical function(s).

Although the flowcharts of FIGS. **2**, **3**, and **4** show a specific order of execution, it is understood that the order of execution may differ from that which is depicted. For example, the order of execution of two or more blocks may be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIGS. **2**, **3**, and **4** may be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the blocks shown in FIGS. **2**, **3**, and **4** may be skipped or omitted. In addition, any number of counters, state variables, warning semaphores, or messages might be added to the logical flow described herein, for purposes of enhanced utility, accounting, performance measurement, or providing troubleshooting aids, etc. It is understood that all such variations are within the scope of the present disclosure.

Also, any logic or application described herein, including the resource allocation application **114**, that comprises software or code can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor **502** in a computer system or other system. In this sense, the logic may comprise, for example, statements including instructions and declarations that can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a "computer-readable medium" can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

The computer-readable medium can comprise any one of many physical media such as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM) and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

Therefore, the following is claimed:

1. A non-transitory computer-readable medium embodying a program executable in at least one computing device, comprising:

code that generates usage data associated with a past usage of a plurality of application program interfaces;

code that calculates, as a function of a weighted average of the usage data, a plurality of thread allocation limits, each of the thread allocation limits corresponding to one of the application program interfaces;

code that recalculates the thread allocation limits responsive to a new application program interface being added to the application program interfaces;

code that increases a first one of the thread allocation limits responsive to a current resource usage of a corresponding one of the application program interfaces approaching the first one of the thread allocation limits;

code that decreases a second one of the thread allocation limits contemporaneous to increasing the first one of the thread allocation limits; and

wherein the first one of the thread allocation limits is increased and the second one of the thread allocation limits is decreased responsive to an overall system capacity being above a threshold and the second one of the thread allocation limits being above a minimum limit.

2. The non-transitory computer-readable medium of claim **1**, wherein a magnitude of a weight applied to the usage data increases with respect to older usage data.

3. A system, comprising:

at least one computing device; and

a resource allocation application executable in the at least one computing device, the resource allocation application comprising:

logic that generates usage data associated with a past usage of a plurality of application program interfaces;

logic that calculates, as a function of the usage data, a plurality of resource allocation limits, each of the resource allocation limits corresponding to one of the application program interfaces; and

logic that recalculates the resource allocation limits responsive to an event.

4. The system of claim **3**, wherein the resource allocation limits are recalculated as a function of a maximum allowable resource allocation limit change.

5. The system of claim **3**, wherein the logic that calculates the resource allocation limits further comprises logic that calculates a weighted average of the usage data.

6. The system of claim **5**, wherein a magnitude of a weight applied to the usage data increases with respect to older usage data.

7. The system of claim **3**, wherein the resource allocation application further comprises:

logic that increases a first one of the resource allocation limits responsive to a current resource usage of a corresponding one of the application program interfaces approaching the first one of the resource allocation limits; and

logic that decreases a second one of the resource allocation limits contemporaneous to increasing the first one of the resource allocation limits.

8. The system of claim **7**, wherein the first one of the resource allocation limits is increased and the second one of the resource allocation limits is decreased responsive to an overall system capacity exceeding a threshold.

9. The system of claim **7**, wherein the first one of the resource allocation limits is increased and the second one of the resource allocation limits is decreased responsive to the second one of the resource allocation limits being above a minimum threshold.

10. The system of claim **3**, wherein each of the application program interfaces is associated with one of a plurality of priority tiers, and the resource allocation limits are calculated as a function of the priority tiers.

11. The system of claim **3**, wherein the resource allocation application further comprises logic that, responsive to a current usage of one of the application program interfaces approaching a corresponding one of the resource allocation limits, initiates a resource capacity increase associated with the one of the application program interfaces.

12. The system of claim **3**, wherein the resource allocation limits comprise a maximum number of threads allocated to a corresponding one of the application program interfaces.

13. The system of claim **3**, wherein the resource allocation limits comprise at least one of a number of database connections, an amount of memory, or a number of sockets allocated to a corresponding one of the application program interfaces.

14. The system of claim **3**, wherein the event comprises an addition or deprecation of one of the application program interfaces to the plurality of application program interfaces.

15. The system of claim **3**, wherein the event comprises a passage of a predefined interval.

16. A method, comprising the steps of:

sampling, in a computing device, past transaction data associated with a plurality of application program interfaces;

calculating, in the computing device, a plurality of resource allocation limits as a function of the past transaction data;

recalculating, in the computing device, the resource allocation limits responsive to a satisfaction of a predefined condition; and

wherein each of the resource allocation limits corresponds to one of the application program interfaces.

17. The method of claim **16**, further comprising the steps of:

increasing a first one of the resource allocation limits responsive to a current usage of one of the application program interfaces corresponding to the first one of the resource allocation limits exceeding a threshold; and

decreasing a second one of the resource allocation limits contemporaneous to increasing the first one of the resource allocation limits.

18. The method of claim **17**, wherein the steps of increasing and decreasing are performed responsive to the second one of the resource allocation limits exceeding a minimum threshold.

19. The method of claim **17**, wherein the steps of increasing and decreasing are performed responsive to an amount of overall system capacity exceeding a threshold.

20. The method of claim **16**, wherein the resource allocation limits comprise a maximum number of threads allocated to a corresponding one of the application program interfaces.

21. The method of claim **16**, wherein the step of calculating comprises calculating, for each of the resource allocation limits, a weighted average of the past transaction data associated with a corresponding one of the application program interfaces.

22. The method of claim **16**, wherein the predefined condition comprises an addition or deprecation of one of the application program interfaces.

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